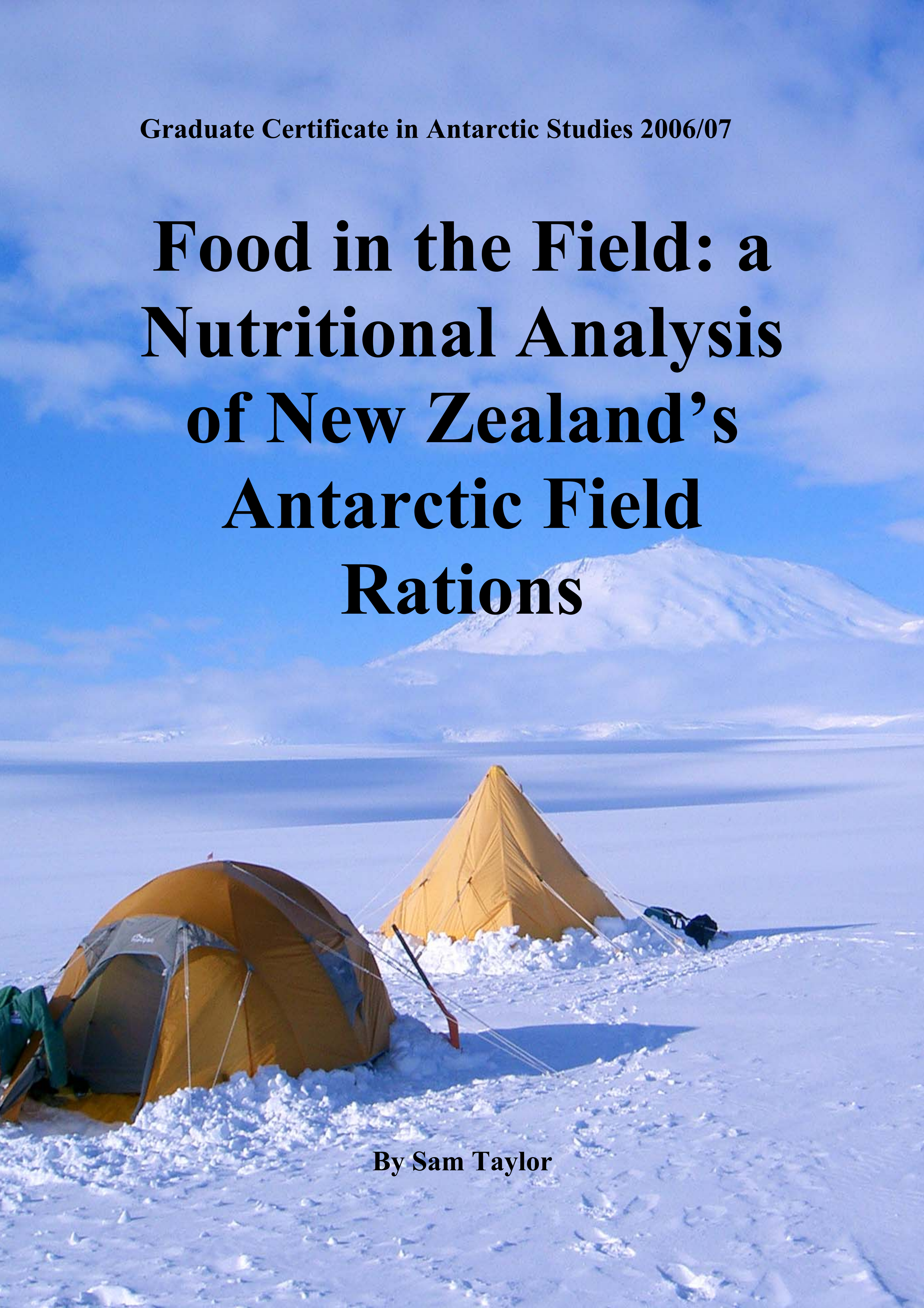
Graduate Certificate in Antarctic Studies 2006/07

Food in the Field: a Nutritional Analysis of New Zealand's Antarctic Field Rations



By Sam Taylor

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Introduction

The area of field nutrition in Antarctica has undergone extensive development during the course of Antarctic exploration and has been the focus of many studies by nutritionists and physiologists looking to understand the dietary requirements of personnel working in Antarctic conditions.

Early expeditions led by Scott, Shackleton and Mawson drew attention to the harsh realities of living in Antarctica for extended periods and many of these men suffered from diet-related problems, compounded by stresses already being experienced in conditions of extreme cold and physical exhaustion (Taylor 1992).
Dietary shortfalls in energy intake and vitamins were common in many early field parties, which affected the health of expedition members such as Lieutenant Evans who died of scurvy on Scott’s 1910 Expedition (Cherry-Garrard 1951).

A sledging expedition led by Sir Douglas Mawson at the same time as Captain Scott’s fateful return from the pole experienced dietary problems of a different nature, when Mawson and his companion Mertz were forced to eat their dogs. They were afflicted by hypervitaminosis-A, a type of vitamin toxicity resulting from the consumption of large amounts of vitamin A from the livers of the huskies (Shearman 1978). This condition eventually killed Mertz, and Mawson was lucky to survive (Shearman 1978).

Weight loss resulting from physical exertion is common in many Antarctic expeditions and it has been shown that sledging requires a much higher calorie intake than ordinary field rations provide, in order to maintain energy balance (Orr 1965). Fiennes (2003) demonstrated that the severe weight loss recorded by Scott’s south-pole sledging team was due to a massive calorie deficiency in their diets, coupled with high levels of energy expenditure while manhauling.

All of these diet-related afflictions reinforced the need to provide a diet that would meet the requirements of the human body in terms of calorific value (energy) and nutrient content while remaining practical in a field environment. Since these early experiences of Antarctic survival, advances in the level of nutrition provided to Antarctic personnel have increased in step with improved knowledge of human physiology and metabolism. New technology has improved food preservation and processing techniques and there is now greater logistical capability providing support to Antarctic programmes. Having faster, more reliable transportation has allowed more frequent re-supply of bases and field camps with fresh food, especially over the summer field season, greatly improving the range of food available to Antarctic personnel (Taylor 1992).

Although most bases are now equipped with more than adequate food supplies even as far inland as the South Pole, there are still issues associated with maintaining the food provided to isolated field groups. The main concern for these field events is that they may have to cope for long periods without re-supply so the food they take must be preserved, and remain useable after several months. Field rations also need to be durable in order to handle exposure to a broad potential temperature range over the summer field season, which could subject the food to many freeze-thaw cycles.

As field groups can potentially be surviving away from base for the entire field season, vitamin and mineral deficiencies can begin to develop in personnel. To combat this issue, field rations must contain or be supplemented with essential vitamins and minerals.

There is also debate over what proportion of macronutrients should be provided in field rations, and there have been trials of alternative dietary regimes, which have placed emphasis on increasing the proportion of fats, carbohydrates or protein given to personnel. There is currently no international agreement on the best composition of nutrients in an Antarctic diet (Orr 1965, Ventsenostsev 1973). There are standardised field rations within national Antarctic programmes but the types of food contained in these rations is generally more a reflection of social trends and convenience of use than their nutritional merit, unless providing for particularly high levels of energy expenditure (Taylor 1992).

Antarctica New Zealand issues field rations as a twenty person-day ration box to field events, which will allow for a standardised comparison of field rations between years.

This report aims to analyse the composition of New Zealand's Antarctic field rations in order assess the nutritional values of ration boxes for field personnel. Research on current knowledge of human metabolism and dietary requirements in Antarctic conditions will be used to assess the suitability of New Zealand's current Antarctic field rations.

Rationale for Study

This report was inspired by a personal fascination in the limits of the human body to endure physical and metabolic hardship and the ability of the Antarctic environment to compound these stresses. Reading the historical accounts of expeditions during the heroic era of Antarctic exploration gives anyone an admiration and respect for these men and the environment that they lived in, especially considering what they accomplished with the limited resources they were provided with.

After experiencing some of the challenges associated with living in an Antarctic field camp (albeit briefly) on the Ross Ice Shelf, I was persuaded to look at the nutritional content of modern Antarctic field rations. This report aims to investigate the nutritional requirements of Antarctic field personnel and provide a summary of the structure of New Zealand's Antarctic field rations in order to meet these requirements. The report will also examine the potential for future development in the needs of field personnel and look at the potential for improvements in the composition of field ration boxes provided to New Zealand field events in Antarctica.

Methods

Historical records were used to gain an understanding of the main health problems encountered in the Antarctic field environment while more recent publications were used to shed light on the dietary significance of these problems.

Contents lists of field ration boxes were obtained from past Antarctic New Zealand field manuals and were entered onto a computer database for nutritional analysis. The software used for the analysis of New Zealand's Antarctic field rations was the 'Serve 52' nutritional program, which was capable of calculating proportional amounts of macronutrients (protein, fat, carbohydrate, alcohol) and total energy (kilojoules) contained within a food list of specific types and quantities.

Due to the historical nature of some field ration lists, it was necessary to select some food items for use as a proxy for the original items, as either the food list did not contain enough information to identify the exact type of food or the brand of food no longer existed and was not represented in the database.
The results of the nutritional analysis were graphed to allow for comparison of total energy content and macronutrient proportions of New Zealand field ration boxes through time.

Peter Cleary, Operations Advisor for Antarctica New Zealand was interviewed to gain a first-hand perspective on the challenges associated with structuring the current Antarctic field rations provided by Antarctica New Zealand and the requirements they must fulfil. The potential issues arising in the future of Antarctic nutrition were also identified and recommendations from a previous review of Antarctic nutrition for Antarctica New Zealand have been discussed. Some possible mitigation measures were also proposed.

The Historical Approach to Field Rations

In the early expeditions to Antarctica, personnel in coastal areas were able to supplement their stores of preserved food by harvesting seals, penguins and fish. Besides decreasing the reliance on stored food and increasing the time an expedition could be sustained on the ice, the fresh supply of meat also provided them with a source of vitamin C, which helped prevent scurvy (Fiennes 2003).

For men living around the coast of Antarctica, the supply of natural resources could support their nutritional requirements almost indefinitely as was the case on Shackleton's voyage of 1914-1916 after their ship the Endurance sunk (Piggott 2004). Frank Hurley, one of the stranded expedition members noted that seals and penguins had evolved to provide a valuable resource for castaways as seal blubber provided enough fuel to cook the meat of the animal as did penguin skins (Piggott 2004).

Up until 1959, the New Zealand Antarctic Operations Manual was still advocating the use of local food sources, stating in the manual under a section titled 'General Hints' to "Discard all inessentials and cut weight to a minimum. Experience has shown that around the coast, natural food abounds (penguins, seals, skuas etc) and the use of this will obviate hauling pounds of tinned food." (New Zealand Antarctic Programme 1956: 61). This reinforces that one of the main considerations for field teams at this time was the weight of field rations that would have to be carried on their sledges, which is now not such a problem as most bases use mechanical equipment instead of men and dogs to transport supplies into the field.

Although historical expeditions gained some important vitamins by making use of the coastal fauna as a food source, the approach to field rations during the heroic era lacked knowledge of the importance of micronutrients in the diet, and many foods in the field rations at this time were deficient in essential vitamins (Fiennes 2003). The sledging rations on Scott's fateful 1911 expedition were very basic (Table 1) and lacked many of the more common sources of vitamin C (Orr 1965, Fiennes 2003). This and an insufficient energy component were the main dietary reasons isolated sledging parties in the interior of the continent found their health deteriorated over time, as they were not obtaining the nutritional benefit they required from their field rations and were subject to developing scurvy, as their bodies slowly exhausted their vitamin C (Fiennes 2003).

Traditionally, a heavy reliance was put on the use of Pemmican, a combination of fat and meat powder (Bell 1957). This formed a staple part of the diet of many early expeditions due to its high calorie content and durability and was still being used up until the 1950's (Table 1). Later expeditions included a much wider variety of foods in the field rations such as milk powder, dried onion, and potato powder (Table 1) which increased the intake of vitamin C for field personnel without the need to take supplements or perishable fresh foods to the field (Orr 1965).

Historical Antarctic expeditions generally had a much higher energy requirement than present day field events due to the higher physical workload performed by the groups while transporting their equipment overland using sledges. The physical demands of sledging in Antarctica meant it was important for expedition members to maintain a high calorie intake to replace the energy expended while working. Table 1 shows that most early expeditions budgeted for a daily ration for each man of about 5000 calories, although in many cases this was probably insufficient (Fiennes 2003).

Table 1. Comparison of sledging rations from historical expeditions (source: Orr 1965: 89)

	Winter journey, 1911 (Scott, 1913)	Scott's Summit ration, 1911–12 (Scott, 1913)	Mawson, 1911 (McLean, 1919)	Arctic Air Route, 1930–1 (Lindsay, 1932)	British Grahamland Expedition, 1934–7 (Rymill, 1938)	Falkland Island Dependencies Survey, 1948–50 (Fuchs, 1952)	Falkland Island Dependencies Survey, 1958 (Orr, 1963)	MRC Experimental Box, 1959 (Lewis *et al.* 1963)
Pemmican	12	12	8	8	5·6	5·6	—	—
Biscuit	16	16	12	4	2·7	3·75	4·8	4·0
Butter or margarine	4	2	2	8	5·6	4·8	4·8	5·0
Sugar	—	3	4	4	3·2	3·2	3·1	3·2
Cocoa	—	0·57	1	1	0·8	0·8	0·6	1·5
Tea	—	0·86	0·25	—	—	0·4	0·2	0·25
Chocolate	—	—	2	3	2·4	2·4	0·4	4·0
Milk	—	—	5	2	1·6	1·6	1·6	2·0
Pea flour	—	—	—	2	1·6	0·8	—	—
Oats	—	—	—	3	2·0	2·5	2·4	2·0
Potato powder	—	—	—	—	—	0·8	0·4	1·0
Onion flakes	—	—	—	—	—	0·4	0·4	0·1
Nescafe	—	—	—	—	—	0·2	—	0·25
Marmite	—	—	—	—	—	0·2	0·1	0·1
Bacon	—	—	—	—	—	—	0·8	—
Meat bar	—	—	—	—	—	—	5·0	6·0
Soup powder	—	—	—	—	—	—	1·0	1·0
Fruit bar	—	—	—	—	—	—	1·5	0·75
Curry powder	—	—	—	—	—	—	—	0·25
Cheese	—	—	—	—	—	—	—	2·0
Glucose lemon	—	—	—	—	—	—	—	1·0
Sweets	—	—	—	—	—	—	—	1·0
Pumpernickel	—	—	—	—	—	—	—	0·45
oz/man day	32	34·43	34·43	35	25·5	27·45	27·1	35·85
kcal/man day	5100	5100	5100	5500	4000	4100	3900	5400
Protein (%)	22	28	33	27	19	17	17	14
Fat (%)	42	31	25	34	38	38	37	25
Carbohydrates (%)	36	41	42	39	43	45	46	61

The other feature of Antarctic field rations that has been intensely scrutinised is the proportion of essential macronutrients contained in the diet. Previous studies have been conducted to assess the benefits of consuming diets that are rich in fats, carbohydrates or proteins or a balance of all three.

Apsley Cherry-Garrard, Bill Lashley and Henry Bowers conducted one of the earliest experiments seeking to identify the best proportions of dietary components for Antarctic conditions while on Scott's 1910 expedition (Cherry-Garrard 1951). Their trial, although largely based on personal preference, determined that supplementary fat in the form of butter was needed in order to feel satisfied with their daily ration allocation. Extra fat was also added to the diet to give more protection against the cold (Cherry-Garrard 1951).

More recent sledging journeys by the British Antarctic Survey found using a high proportion of fats was necessary to provide the large amount of calories required for sledging while keeping weight to a minimum (Edholm 1974, Stroud and Jackson 1996).
It is clear from the historical accounts that using fat as the main source of dietary calories provides a relatively lightweight energy source and up to 57% of calories on B.A.S sledging journeys came from metabolism of fat in the diet (Edholm 1974). This use of fats as the primary energy source during long periods of physical work has been maintained, and a similar proportion was included in the diet of Mike Stroud and Ranulph Fiennes' unassisted crossing of Antarctica, where they obtained 56.7% of their energy from dietary fat (Stroud and Jackson 1996).

Levels of protein in early field rations were probably excessive, largely due to the reliance on pemmican as a primary constituent of the ration boxes and resulted in protein contents of up to 33% in some expedition field rations (Orr 1965).
Carbohydrates are the other important macronutrient component of field rations and it was found during trials on the Australian National Antarctic Research Expedition (A.N.A.R.E) that men developed cravings for sweet things and not fatty things (Law 1957). Sugar was used extensively to satisfy this craving for sweetness and provided a readily absorbed source of energy from carbohydrate (Law 1957).

In the past, varying proportions of nutrients have been trialled in field rations, with most diets providing sufficient calories except during high-intensity sledging. The ANARE expedition in 1956 recommended using a ratio 1:1.5:1.75 for protein, fat and carbohydrates, which was a higher proportion of fat and protein than the standard recommendations at the time (Law 1957). It was demonstrated by Orr (1965) that some of the most successful sledging journeys in the past place a higher emphasis on the amount of fat in their rations, using diets made up of about 20% protein, 40% fat and 40% carbohydrate.

Overall, the main goal of diets on historical expeditions was to obtain enough calories to maintain an energy balance, and this was usually done by increasing the fat content. Personal preference dictated the amount of fat that was eaten with the field rations (Orr 1965) and sometimes the level of energy expenditure exceeded the maximum physical limits of the body to assimilate energy. Fiennes (2003) stated that during his unassisted crossing of Antarctica, they consistently burned 7000 calories per day and this energy drain peaked at 11000 calories per day during his ascent to the polar plateau. This amount of physical activity resulted in significant weight loss, as the human body cannot absorb more than 7000 calories in any 24 hr period (Fiennes 2003).

Nutritional Requirements of Personnel in Antarctica

The nutritional requirements of an individual working in the Antarctic depends on a range of factors including the size of the person, the amount of physical work they perform, environmental conditions they are exposed to, their basal metabolic rate (BMR) and their degree of acclimatization (Orr 1965, Law 1957). It is generally accepted that personnel put on weight while stationed in Antarctica as they consume more calories when exposed to cold Antarctic conditions than they would in temperate climates (Fig. 1).

There are also recognized seasonal fluctuations in the weight of Antarctic staff and most staff put on weight over the winter, even after reducing their calorie intake, purely due to the fact that physical activity outdoors are greatly inhibited in the dark, cold winter months (Taylor 1992). There is a subsequent reduction in weight with the advent of spring, and the energy requirement of the staff increases again during the summer as fieldwork increases (Taylor 1992).

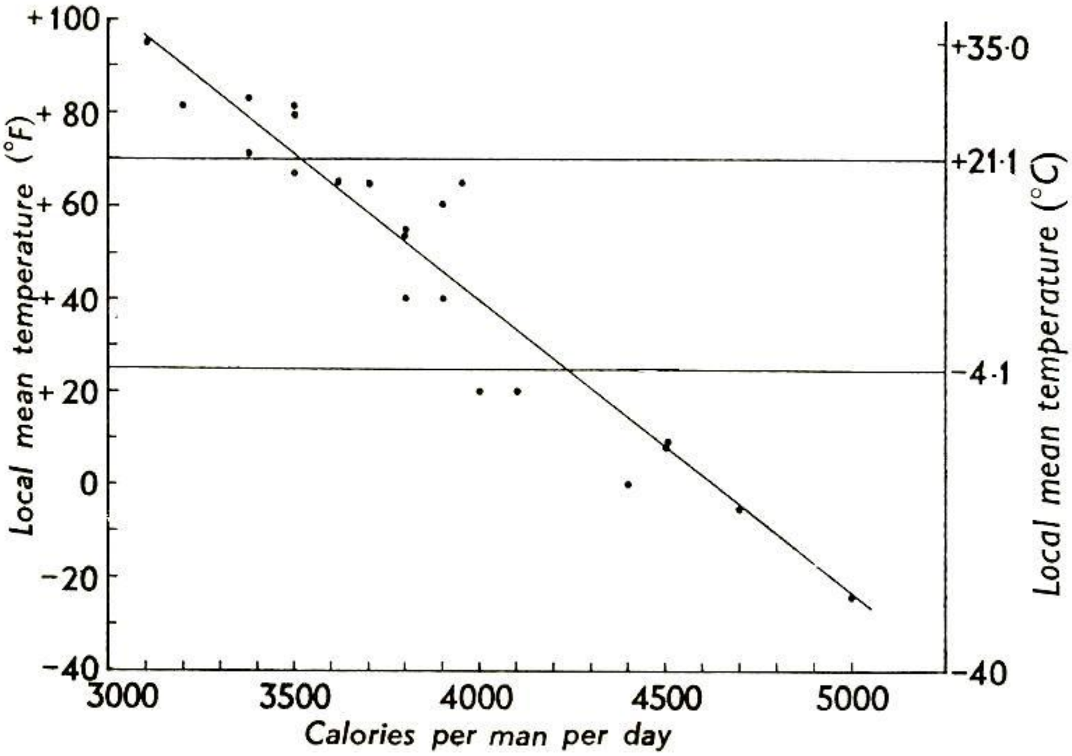

Fig. 1 Voluntary calorie intake in soldiers at different temperatures (source: Johnson and Kark 1947 in Burton and Edholm 1955:158)

The reasons suggested for the apparent increase in appetite at colder temperatures (Fig. 1) are varied and include psychological and physiological influences. It has been suggested that the main reason for increased calorie intake is to provide metabolic energy to maintain body temperature at colder temperatures, although it could be argued that an increased physical workload among soldiers in cold temperatures was the reason for the calorific increase (Johnson and Kark in Burton and Edholm 1955). In any case, Fig. 1 would suggest that personnel have a desire to consume more energy at colder temperatures such as on the Antarctic plateau. Warmer areas such as the Antarctic Peninsula may have a less dramatic effect on calorie intake for field personnel.

Burton and Edholm (1955) noted in their experiments looking at metabolic response to cold that appetite increases immediately in subjects but bodily heat production increases slowly in personnel exposed to cold, which usually resulted in an initial weight gain. Other explanations for this phenomenon of cold-induced appetite are that general activities performed in cold conditions could have a higher metabolic cost although it is also possible that increases in appetite with cold as shown in Fig. 1 are partly a function of increased basal metabolic rate (Burton and Edholm 1955, Westerterp-Plantenga 1999).

Energy requirements for personnel working in Antarctica are generally much less now than they would have been back in the early 20th century due to the increased use of mechanised transport and an improved ability of Antarctic personnel to modify their immediate environment through heating systems and insulated clothing and accommodation. Nevertheless, energy expended in Antarctica must be replaced if people are going to survive there, so field rations provided must contain enough energy to balance what the body uses. Energy requirements differ according to the local conditions and intensity of workload and Table 2 illustrates some average energy intakes between bases.

Table 2. Comparison of energy intakes between programmes (source: Taylor 1992: 41) (IBEA: International Biomedical Expedition to the Antarctic).

Expedition	Calculated Energy Intake Kcal/day	KJ/day	Average Subject Weight (kg)
Australia (Fletcher)	3 420	14 364	75.9
England (Acheson)	3 210	13 482	72.0
(Edholm)	3 610	15 162	77.3
(Easty)	3 600	15 120	77.0
Japan	2 815	11 823	66.9
Russia	3 653	15 343	79.4
America	4 250	850	81.3
France (Rivolier)	3 200	13 440	–
IBEA	3 400	14 200	–

It would appear from the information contained in Table 2 that there are differences in the average amount of energy consumed by personnel from different countries. Taylor (1992) states that the calorie intake on an expedition is affected more by the country's social tastes and food availability at their station than any particular environmental variable. It has also been stated by the US National Research Council (1982) that calorific requirements for someone in Antarctica with an average level of activity are between 3000-3600 kcal/day, which fits the figures provided by the majority of countries in Table 2.

It should be noted that Table 2 refers to staff at bases. Field staff are likely to have a higher energy requirement than base personnel. The amount of calories required to maintain bodyweight while sledging for example range from 5000 kcal/day for dog sledging (Edholm 1974, Orr 1965) to as much as 7000 kcal/day when manhauling sledges (Fiennes 2003).

It has become apparent that personnel working in Antarctica have a requirement for a high energy-intake in their diets. From the published material, it would appear that the main necessity for increased calorie intake is to balance the energy expended during increased physical workload although this is likely to be compounded by other causes.

Macronutrients

There are presently many conflicting assessments of the ideal proportions of macronutrients making up the energy requirement of Antarctic Field rations and again these are generally decided according to social tastes within the country of origin. The US National Research Council (1982) suggests a diet consisting of 15% protein, 35% fat and 50% carbohydrate. This fits with figures published by the International Biomedical Expedition to the Antarctic, which detail similar proportions of macronutrients consumed during their expedition to the Antarctic Plateau (IBEA in Taylor 1992).

-Protein

Dietary intake of protein is essential in order to supply the body with the materials it needs for growth and development of organs and tissues (Brouns 1993). When the body is not obtaining enough protein from the diet, particularly the essential amino acids that the body needs from protein sources, then bodily growth is weakened (Brouns 1993). It has also been postulated that sufficient protein intake increases the body's resistance to stress such as trauma, infection and nervous strain while insufficient protein intake reduces the absorption of vitamins (Ventsenostsev 1973).

Unlike the large stores of energy that the body retains as fat or glycogen, it has no protein reserve storage and all protein contained in the body is utilized in various structures (Brouns 1993). Any unused protein is metabolised to release amino acids, which are oxidised to release energy and excess nitrogen is excreted as urine (Brouns

1993). In situations of energy deficits as were experienced by Scott and his men, amino acids may also be used as a fuel source Brouns 1993).

In European countries, the recommended intake of protein for adult males is in the range of 54-105g and for adult females it should be between 43-81g but in general the protein intake for healthy people should be between 10-15% of total daily energy intake (Brouns 1993).

It is important for sufficient protein to be included in Antarctic field rations to provide for muscle repair after exercise and to support enzymatic adaptations (Brouns 1993).

-Fat

Physical exercise requires muscles in the body to burn energy and this chemical energy is sourced from carbohydrate and fat reserves (Brouns 1993). When the body is working at low intensities or is in a resting state, the oxidation of fat is the primary source of energy. This oxidation process is stimulated during exercise to release more fatty acids, which are oxidised to produce energy in the mitochondria of muscle cells (Brouns 1993). This process of fat mobilisation, transport and oxidation is regulated by the hormones adrenaline and noradrenaline (Brouns 1993).

Fat is the energy source with the greatest energy density, yielding 37.5 kJ/g compared with 16.9 kJ/g for carbohydrate (Brouns 1993). For this reason, fat makes up a large proportion of sledging rations as it provides a large amount of energy for minimum weight (Stroud and Jackson 1996).

Fat reserves in the body can also be used as a source of energy to generate heat (Jessen 1980). Secretion of noradrenaline stimulates the utilization of fat stores in adipose tissue, which supply the energy for this increased demand in order to increase body heat without shivering (Jessen 1980). This has implications for the susceptibility of lean personnel to cold Antarctic environments.

In a healthy non-trained individual, body fat content is between 20-35% in females and 10-20% in males and it is thought that individuals in Antarctica with a higher level of subcutaneous fat are less prone to suffer from cold related conditions. The thermal conductivity of fat is much lower than skin or muscle, and ordinary fat has a poor blood supply, which prevents loss of heat from the circulatory system (Edholm 1978). For these reasons, fat people are generally better insulated than thin ones (Edholm 1978), and it may be thermally advantageous for Antarctic personnel to maintain a layer of subcutaneous fat on their bodies

-Carbohydrate (CHO)

Carbohydrate is the primary fuel for muscles during high-intensity work and is stored as long chains of glucose molecules coupled to form glycogen in the liver and muscles (Brouns 1993). At any one time, there is approximately 100g of glycogen stored in the liver and this glycogen reserve peaks after meals but decreases during fasting periods when glucose is supplied to the bloodstream to maintain blood glucose levels (Brouns 1993).

During physical exertion, the muscles increase uptake of blood glucose to obtain energy, while the liver is stimulated to maintain blood glucose levels (Brouns 1993). Muscle glycogen is used secondarily to the liver source and this only occurs when liver glycogen stores are exhausted. As stored glycogen is depleted to levels below an acceptable threshold to maintain blood glucose, hypoglycaemia develops, eventually leading to the oxidation of fats and protein as alternative energy sources (Brouns 1993). Numerous studies have been conducted seeking to identify dietary effects on cold tolerance in man and it was shown that foods high in carbohydrate or fat were preferable to high protein foods (Mitchell et al. in Orr 1965).

Micronutrients

One of the key nutritional requirements when living in the Antarctic environment are essential vitamins and minerals (micronutrients) which are equally important in the maintenance of healthy bodily functions in Antarctic personnel (Brouns 1993). Minerals are important materials in the structure of the human body from a complete skeleton, down to a cellular level, while vitamins are utilised in almost all biological processes and act as the catalysts for many biological reactions (Brouns 1993).

-Vitamins

Vitamins are one group of micronutrients essential to human health, and are associated with most biological functions. Vitamins are used to help synthesise proteins and neutralise free radicals with their antioxidant properties (Brouns 1993). Due to their importance in the functioning of metabolic processes, deficits in essential vitamins can affect metabolism, leading to illness (Brouns 1993). Vitamin content in the human body is affected by food intake, vitamin density of food, absorption efficiency and losses from the body (Brouns 1993).

Vitamin A (beta-carotene) is an antioxidising nutrient that may be of greater importance in cold or high altitude environments (Askew 1995). It was identified that vitamin A helps to protect the body from immunosuppression caused by exposure to long-wave UV light outdoors (Fuller et al. in Askew 1995).

Vitamin B12 and folic acid are two key vitamins that are vital for DNA synthesis and metabolism of fat and protein (Taylor 1992). Vitamin B12 is supplied from animal sources and the human body has a good storage and recycling system for this mineral so it is rare to encounter deficiencies, although strict vegetarians can develop shortages of the vitamin (Taylor 1992).

Folic acid on the other hand is mainly found in fresh vegetables and is heat sensitive; meaning up to 100% of it can be lost during cooking (Taylor 1992). For these reasons, it is difficult to maintain in Antarctic conditions. In contrast to vitamin B12, the body also has difficulty storing folic acid, which means deficiencies become apparent over a short period (Taylor 1992).

Vitamin B1 (Thiamin) helps to oxidise carbohydrate (CHO) to provide energy. Recommended intake is related to energy expenditure and CHO intake. People who burn a lot of energy and consume large amounts of carbohydrate may have an increased requirement for vitamin B1, although deficiencies are sometimes seen in both active and inactive individuals (Brouns 1993).

It is well documented that in cold conditions as found in Antarctica, there is increased consumption of vitamin B1 in the human body (Efremov et al. in Ventsenostsev 1973). In general, the vitamin needs of people exposed to stress, physical load and cold are increased, in particular their requirement of vitamin C and B complex (Vasyutochkin et al in Ventsenostsev 1973).

Riboflavin (Vitamin B2) is used in energy metabolism at the intra-cellular level and has been related to energy intake. It has not been shown to increase athletic performance and little is known about the effects of deficiencies of the vitamin (Brouns 1993).

Vitamin B6 (Pyroxidine) is also important in protein synthesis and is seen as crucial to increase muscular strength in individuals (Brouns 1993). The recommended intake for males is higher than for females.

Vitamin B12 (Cyanocobalamin) is another influence on protein synthesis and it works as a coenzyme in the metabolism of nucleic acids. As the only source of vitamin B12 is from meat, vegetarians can become deficient as well as people with impaired absorption (Brouns 1993).

Niacin is another important vitamin and works as a coenzyme in the glycolysis cycle to metabolise energy. It also helps with respiration in tissues and fat synthesis. It is slightly different in that it can be synthesized in the body from the amino acid tryptophan (Brouns 1993).

Pantothenic Acid (PA) is an intermediary in the citric acid cycle resulting from CHO and fat metabolism. There is currently not enough evidence to set a recommend daily allowance (RDA), although a safe daily intake is thought to be between 4-7 mg (Brouns 1993).

Vitamin C (Ascorbic Acid) is one of the most widely known antioxidants and is commonly supplementary to natural sources. It has a variety of functions but is effective at neutralising free radicals that damage cells and also provides protection to Vitamin E, another antioxidant (Brouns 1993). Vitamin C works as an electron transmitter in enzyme reactions and is involved in the synthesis of carnitine and collagen while also enhancing absorption of iron across the stomach wall (Brouns 1993). The role of Vitamin C was not understood in early Antarctic expeditions and deficiencies in the field rations led to the development of scurvy after long periods in the interior of the continent (Fiennes 2003). It is now understood that consumption of Vitamin C is greatly increased in personnel exposed to intense ultraviolet radiation during the polar summer, which exacerbates the onset of Vitamin C deficiencies (Chekin in Ventsenostsev 1973).

Vitamin E (Alpha- Tocopherol) is another antioxidant and it protects lipids in the cell membranes from oxidation by free radicals. It functions in collaboration with Vitamin C, beta-carotene and Selenium (Brouns 1993). Some studies have indicated that vitamin E supplements raise the testosterone/cortisol ratio of the body, which may have stress reducing qualities (Brouns 1993). It has also been suggested that vitamin E may have a protective (antioxidant) effect at high altitude, which may be significant for personnel working on the polar plateau in Antarctica (Brouns 1993).

Micronutrients

-Minerals

Minerals such as potassium, phosphorus, magnesium, calcium, iron and zinc are essential for the maintenance of skeletal and muscle structure, and play a role in the functioning of the nervous system (Brouns 1993). Bones contain high levels of calcium and phosphate, whereas muscle cells are rich in potassium and magnesium with blood plasma and intercellular fluid providing the main pool of sodium and chloride (Brouns 1993). Loss of these essential minerals can occur through sweat and waste excretions and if uptake does not occurs through absorption from food then cell growth and function can be weakened (Brouns 1993).

Trace elements such as Copper, Chromium and Selenium are also important in biological processes. Trace elements are thought to play a key role in the processing of macronutrients such as fat, protein, carbohydrate and water and a deficiency in trace elements in the diet can cause changes to biochemical and physiological functions affecting health (Brouns 1993).

There are inherent problems in providing the required vitamins and minerals for field personnel in Antarctica due to the environmental constraints restricting the types of food that can the utilised. Obtaining adequate mounts of vitamin C can be a problem as the best source of vitamin C comes from fresh fruit and vegetables, which are difficult to transport and store. Ventsenostsev (1973) noted that the vitamin C content of vegetables diminishes during storage, while cooking destroys 50% of vitamin C and 20% of vitamins A and B1.

Composition of New Zealand's Antarctic Field Rations

While researching the field ration food lists for this report it became clear that the composition of New Zealand's field ration boxes has changed very little since the inception of Scott Base and Fig. 2 below demonstrates the relative consistency of New Zealand field rations.

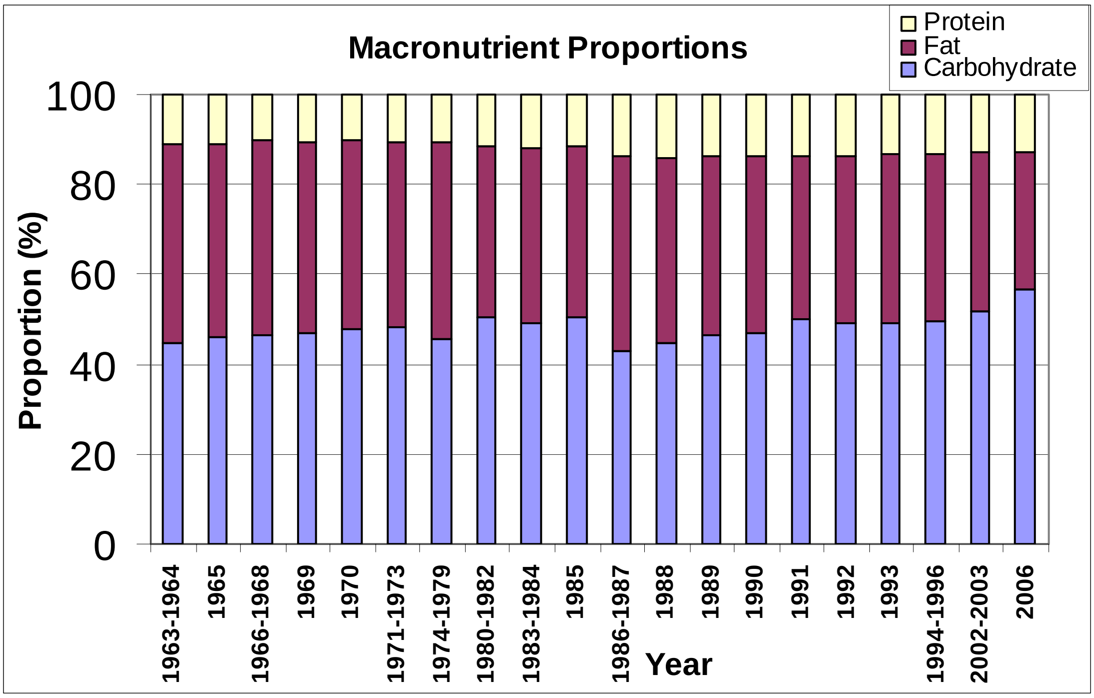

Fig. 2 Proportional energy contribution of macronutrients in New Zealand field rations observed through time,

It is clear from Fig 2. that carbohydrates have consistently provided at least 40% of energy in the New Zealand field rations with the most recent field ration box containing over 50% of energy from carbohydrates. The proportion of energy as fat in New Zealand field rations looks to have decreased slightly since 1986, while the level of protein in field ration diets has remained even at about 10-15% (Fig. 2). These macronutrient proportions all seem to fall within the recommended parameters of a balanced diet as demonstrated in Fig. 3.

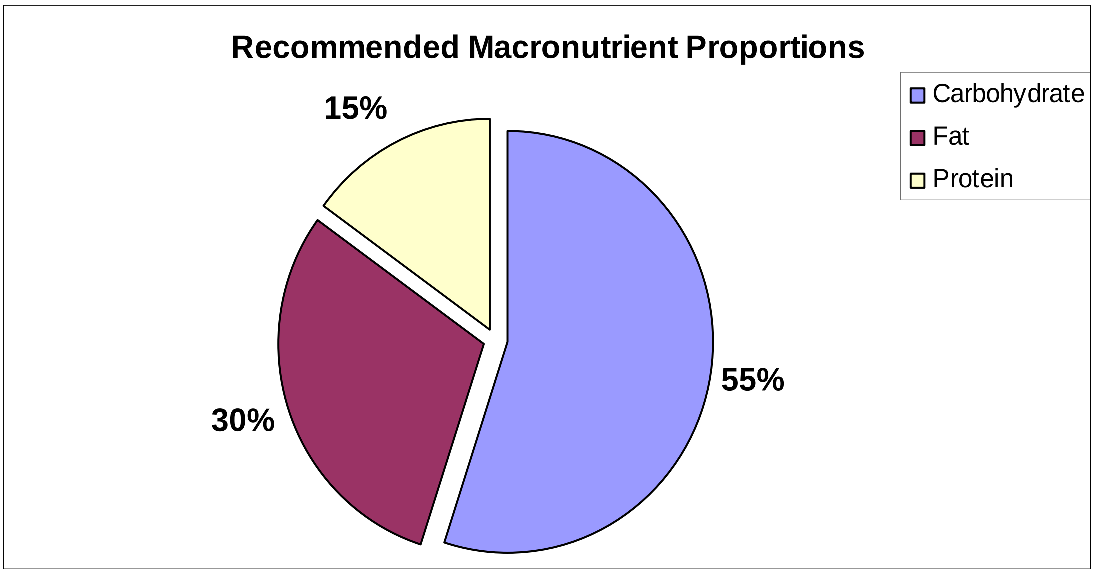

Fig. 3 Recommended dietary macronutrient proportions as outlined by Serve 52 nutritional programme.

Carbohydrate is recommended as the main source of energy intake, followed by fats and lastly protein (Fig. 3). Carbohydrate is important in maintaining adequate blood glucose so it is necessary to maintain a stored carbohydrate in the liver.

Table 3. Energy composition of New Zealand Antarctic field rations (2006)

Nutrient	Amount(g)	Energy (kJ)	Energy Contribution
Alcohol	13.20	386.76	0.0%
Carbohydrate	10,081.60	168,362.71	56.5%
Monounsaturated Fat	810.70	30,563.39	10.2%
Other fats- Glycerol	252.20	9,507.94	3.2%
Polyunsaturated Fat	451.10	17,006.47	5.7%
Saturated Fat	916.50	34,552.05	11.6%
Protein	2,264.60	37,818.82	12.7%
	Total Energy	**298,198.14**	

Table 3 above provides a more in depth look at the macronutrients composing the New Zealand field ration diet in 2006. There is a very small amount of alcohol included in the field rations for this particular year, which was traced to an ingredient in the Christmas pudding.

Table 3 also shows a total energy budget in the 2006 rations of nearly 300,000 kJ although this was for a 20 man-day field ration box. One notable statistic is that saturated fat is almost equal with protein in terms of energy contribution.

Fig. 4 is simply a graphical representation of Table 3 and it clearly shows carbohydrates as the main source of energy in New Zealand field rations.
Protein is the second most abundant source of energy followed closely by saturated fat and then monounsaturated fat. Polyunsaturated fats contributed 6% of energy to field rations and other trace fats such as glycerol made up the final 3% (Fig. 4) The small contribution of alcohol was negligible.

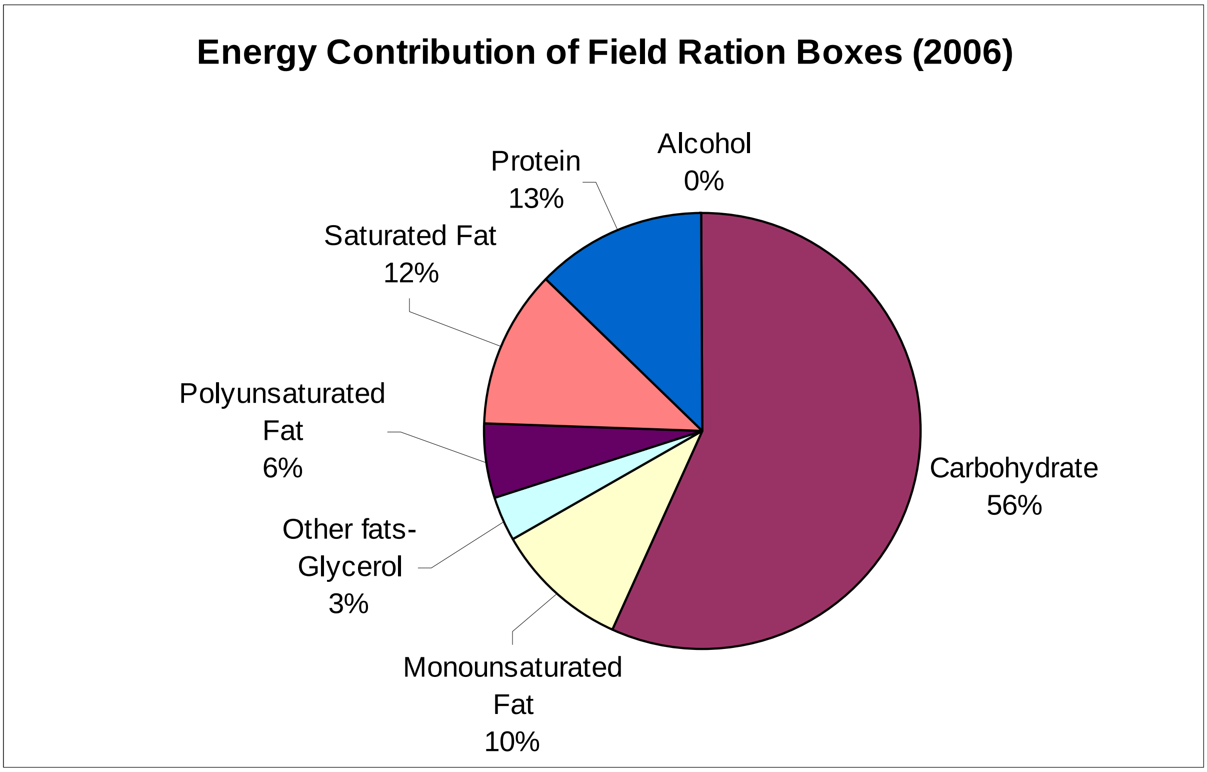

Fig. 4 Energy contribution of New Zealand Antarctic field rations.

Total energy content has been calculated and graphed in Fig. 5 to illustrate changes in field boxes through time. It should be noted that from 1980 to 1985 New Zealand trialled a 14 man-day field ration box, although the level of calories were still very similar to those found in today's 20 man-day ration boxes. From the graph in Fig. 4, it is apparent that there have been several fluctuations in the energy contained in field ration boxes. Energy content peaked between 1974-1979, reaching approximately

85,000 kcal, then reached a low of 57,000 kcal in 1993 before rising back up to about 70,000 kcal in 2006 (Fig. 5).

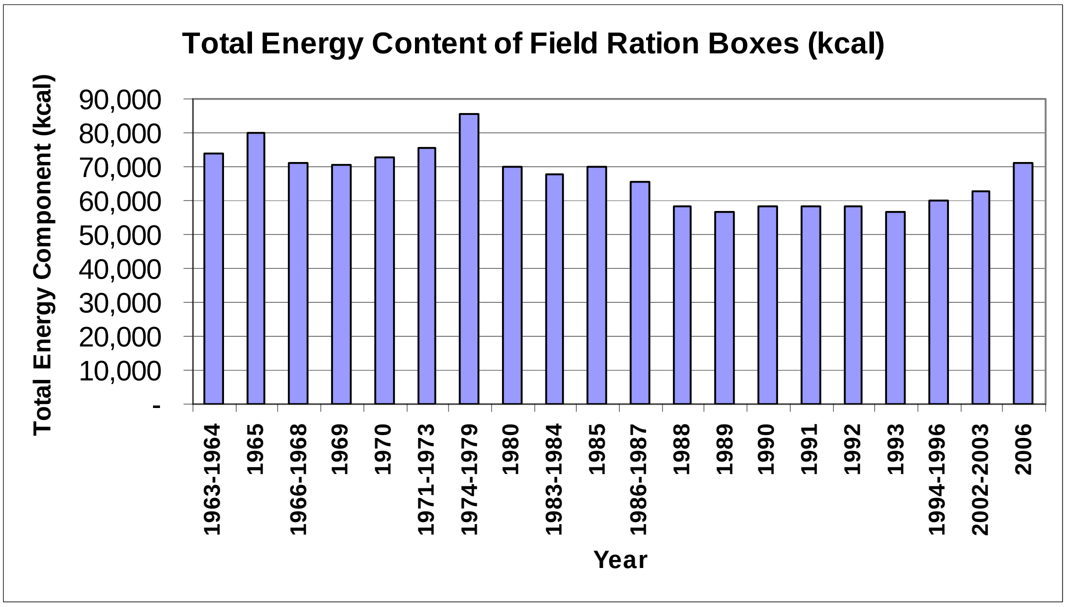

Fig. 5 Total energy content of New Zealand's Antarctic field ration boxes since 1963.

The final graph shows a similar trend in energy values between 1963 and 2006. Unusually, the peak daily energy provided by field ration boxes occurred between 1980 and 1985 when the New Zealand Antarctic Research Programme (NZARP) trialled using fourteen man day ration boxes instead of 20 man-day boxes.

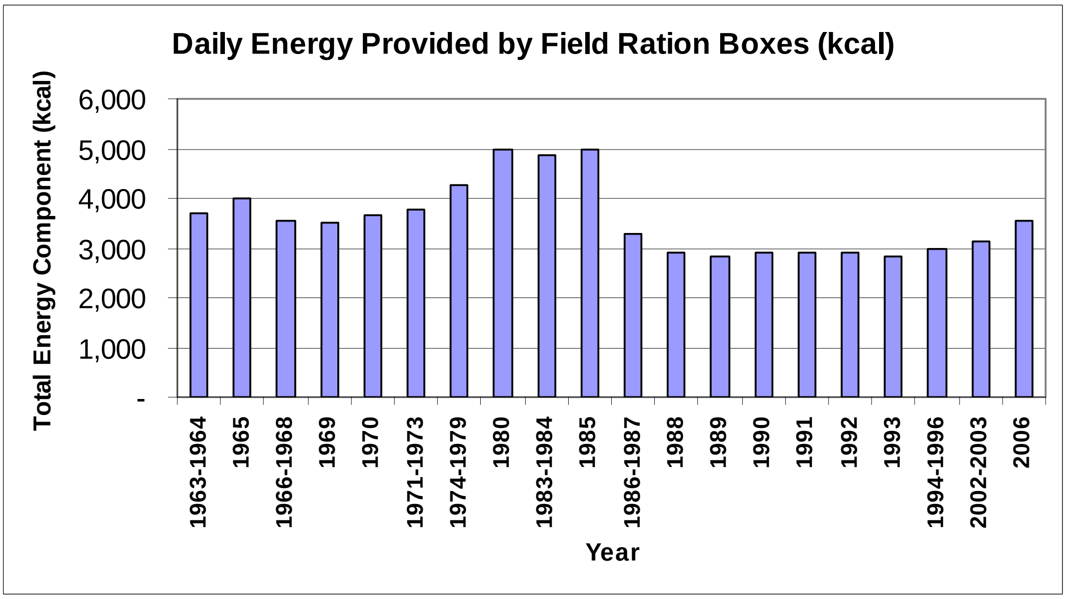

Fig. 6 Daily energy provided per man day from new Zealand Antarctic field rations through time.

Fig. 6 also reflects two trends in daily energy, covering approximately 20 years each. In the first half of the graph from 1963-1985, the daily energy component provided by the Antarctic rations generally remains between 3500 and 6000 kcal.

In the later half of the graph, from 1986-2006 the daily energy intakes dropped to below 3000 kcal /day. Recently the daily rations of food energy have started to increase again and daily energy intake is now at about 3500 calories,

Discussion

The area of Antarctic nutrition has been widely studied since the first expeditions to Antarctica, and although many of the historical issues associated with nutrition have since been mitigated, I was surprised at how little change has occurred in the basic structure of field rations since the 1950's.

It is clear that appetites have been stimulated in people exposed to cold temperatures, although the exact reasoning why is likely to be a culmination of factors. The common suggestions are that working in cold environments is made more difficult by bulky clothing and conditions, the human body naturally burns more energy to maintain body heat and it has even been suggested that there is some deep seeded instinct to eat more during cold periods as a fat storage response (Orr 1965). As for the clothing argument, I think it would produce a negligible increase in energy expenditure, while thermogenesis could be responsible for a slight increase in metabolism as a heat generating mechanism. The instinctive fat storage is unlikely but the most likely explanation for increased appetite in response to cold is a general increase in physical energy expenditure such as when sledging.

It was interesting to note in Table 2 that base personnel from the USA had the highest energy intake in kcal/day and the highest mean weight of individuals. This may have been a reflection of social trends transferred to Antarctica from their country of origin.

Japan was shown to have the lowest energy intake of the countries in Table 2 and the lowest average subject weight, which is probably a reflection of their general physical profile of being small framed people. It was appropriate that they had the lowest daily calorie intake as smaller people generally have smaller appetites.

Overall, there have been only minor changes to New Zealand's Antarctic field rations over the years and the macronutrient composition has generally closely mirrored the recommended proportions of 55% carbohydrate, 30% fat and 15% protein.

A similar level of consistency was evident in the total energy content of New Zealand's field ration boxes, although there was a slight decrease in total calorie content after about 1985. One feature of the graph in Fig. 5 was that despite reducing the size of ration boxes to contain 14 man-days food between 1980-1985, the total energy content of the ration boxes was not seen to fall significantly during this time.

The daily energy intake provided by field rations during the introduction of the 14 man-day ratio box was seen to increase between 1980-1985. This may have been the result of carrying more energy dense rations containing fat, as a safety precaution to mitigate the effect of carrying less bulk. This would fit with the idea that field rations must provide for the worst-case scenario when using the 'one size fits all' approach (Peter Cleary pers comm 2007).

Understandably, there was a notable absence of alcohol in the field rations; however, it would be interesting to look at alcohol consumption on base to determine the energy contribution provided by this non-essential macronutrient.

Future Challenges for New Zealand Field Rations in Antarctica

New Zealand has a long-term commitment to conducting science in Antarctica and as such is likely to be supplying rations for numerous field events in the future. Several issues have become apparent during the course of this report concerning the suitability of field rations in the future.

The first issue to be discussed is how to accommodate vegetarians and vegans in an Antarctic field environment. As it is prohibitively difficult and expensive to re-supply field camps with fresh produce, there is the potential for vegetarians and vegans to become severely limited in what they can eat from standard field ration boxes. Not only is this a problem from a calorific point of view but a severely limited diet also increases the chances of personnel developing nutrient deficiencies if they are in the field for long enough. Nutrient deficiencies are generally less of a problem for omnivorous field personnel as they can assimilate many essential vitamins from meat. One possible solution to the threat of nutrient deficiencies is to take vitamins pills to supplement the field ration diet; however, this still doesn't solve the problem of monotony in a limited diet.

Another issue is that of cooking skills among field groups. There has been a reduction in the ability of field parties to add variety to their diets by using alternative cooking methods, rather than simply demanding more varieties of food (Peter Cleary pers comm 2007). This is possibly due to a new generation of researchers coming from increasingly 'fast-food' societies. Perhaps there needs to be some voluntary skill sharing between established and novice field personnel to enable the transfer of field camp cooking skills between group members.

The other main issue for Antarctic field rations in the future is how the food should be allocated. Many field events arrive at Scott Base in a frantic rush and neglect the preparation of their field rations. Often very little thought is put into which optional items should be taken from the Field Support Officer (FSO), which results in a limited supply of food items in the field restricting dietary variation. Some foods could also be packaged better, however time and financial constraints may prevent repackaging of bulk foods into more manageable containers.

Conclusion

Living in the Antarctic environment has the ability to place the human body under increased physical and psychological stress. People have overcome the majority of challenges presented by living conditions in Antarctica either through micro-scale modification of their environment using clothing and shelter or by physiological adaptation to the environment (Askew 1995).

In order for the human body to cope with physiological changes while maintaining good health the body must be re-fuelled with the essential micronutrients and macronutrients it requires. Antarctic field rations must provide this increase in energy and other key nutritional requirements in order for Antarctic personnel to meet the increased physical demands of working in the field. The future development of New

Zealand's Antarctic field rations will be decided according to the needs arising from New Zealand's ongoing activities in Antarctica and advances in our knowledge of the physical requirements of personnel are essential in order to provide the nutritional requirements for the maintenance of good health in Antarctic field conditions.

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Appendix I: Interview with Peter Cleary, Operations Advisor for Antarctica New Zealand

How long have you been working in the Antarctic domain, and when was your first trip to Antarctica?
-First trip was with NZ Antarctic programme in 1978 as a field assistant/dog handler
-Currently in 17th summer season and have wintered-over three times

Who have you worked for during your career in Antarctica?
-British Antarctic Survey (BAS)
-Antarctica New Zealand
-Adventure Network International

What problems/issues have you experienced with modern Antarctic field rations?
-1930's saw developments in food technology after WWI
-1960/70's sledging burnt 5-6000 calories daily
-hard to carry the bulk of field rations
-rations at this time based on fat (provided 6lbs butter for 2 people for 10 days)

Why has the twenty man-day field ration box been adopted by NZ and UK Antarctic programmes?
-NZ programme inherited it from the British
-ration boxes are width of a standard Nansen sledge
-easy to Count
-can store 20 days dehydrated food in one box

What do you think are essential components of Antarctic field ration boxes?
-choice of Snack foods sometimes questionable
-cooking Skills have been lost- essential to produce varied meals with limited resources
-most packet meals are similar
-BAS diet in 1970's only had three types of dehydrated food-Mutton Curry and Lamb
- Immense Variety of foods not essential but cooking ability needs to be improved to add more variation

With an increase in mechanised transport and equipment in Antarctica, do you think the amount of calories in the NZ field ration boxes is excessive/ adequate/ deficient?
-element of 'one size fits all'
-must allow for worst case scenario-vehicles get stuck, weather turns bad
-windfly/altitude factors could create a calorie deficit
-overall calories provided probably sufficient
-alternative is a self-service approach to food rations- own choice like the Americans- has inherent problems

What are the main challenges to producing suitable Antarctic field ration boxes?
-Individual taste -more vegetarians to accommodate now
-need to maintain balances of macronutrients-vegans are an issue
-size of container-should we buy bulk and repackage or a standard commercial amount
-will always be repetition, now increased range=less repetition
-how do you take account of peoples ability/inability to cook
-often very quick ration preparation times for field events on tight schedules-not enough thinking through of practicalities

Are you aware of any alterative field ration structure in other programmes?
-Australians also have a standard field ration pack
-use 5, 12 or 15 day packs in 'nelly bins'

What are the main changes you have observed in field ration composition during your career?
-rations have become fiddlier-increased snack type foods
-too much range raises expectation-people need to be more practical
-some people now eating better in the field than they would at home

What changes do you envisage occurring to future Antarctic field rations?
-fresh food component currently close to maximum capacity
-field rations still tend to follow social tastes
-ease of preparation and ability to cook are important considerations
-microwaves still a problem as they create a spiked power load on the generators
-transport ability still limiting

Are there any components of current New Zealand field ration boxes that you feel could be improved, how?
-developing a reliance on snack foods instead of proper meals, perhaps too many Pringles and bumper bars
-vegetarian and vegan requirements are a problem-more prone to nutrient deficiencies in long term field camps (BAS would not employ them up until the 1980's)

-frozen food must be kept at -18°C in order to avoid spoilage, not just below 0°C
-increasingly hard to keep field supplies frozen, problems in dry valleys were there's no snowpack to bury supplies
-dehydrated food is a good solution but can react badly to some people

-Luckily the human body can store most vitamins, minerals
-60 to 90 day reserve period before nutrient deficiencies become a problem

Appendix II: Summary of New Zealand's Antarctic Field Rations (Source: Antarctic New Zealand Field Manual 2006:122)

Antarctica New Zealand Field Food Box Contents List **July 2006**
20 Person-Day Food Box Contents

ITEM	Size	Quantity	Weight(grams)
Breakfasts			
Selection of Cereals	450	3	1350
Drinks			
Milk Powder-full cream	400	1	400
Milk Powder-skimmed	400	1	400
Instant Coffee	100	1	100
Tea Bags (approx. 40)	100	1	100
Fruit Drinks-raro mixed flavours	100	3	300
Fruit Drinks-Brandex Energy	80	5	400
Soup, cup-o-soup 4pk	85	2	170
Sugar	500	1	500
Lunch and Spreads			
Crackers/Cabin Bread	500	5	2500
Sweet Biscuits-packet	250	1	250
Fruit Biscuits-Arnotts golden fruit	250	2	500
Vegemite/Marmite	125	1	125
Peanut Butter	125	1	125
Margarine/Butter	500	1	500
Honey	500	1	500
Jam	400	1	400
Lollies-party mix	250	1	250
Chocolate-mixed flavours	150	4	600
Bumper bars-mixed flavours	80	10	800
Fruit bars-mother earth-mixed	60	10	600
Salted mixed nuts	200	1	200
Beef Jerkey	140	2	280
Pringles chips	200	1	200
Shultz pretzl rods	340	1	340
Main Meals			
Maggi Soup-mixed flavours	45	3	135
Maggi Stirfry-cook in pot-mixed	44	3	132
Watties wok creations-sauce sachets	75	2	150
Freeze dried meals-2 serve pkt-mixed	175	5	875
Fish : 1kg foil pouch (tuna)	350	2	700
Potato flakes	225	1	225
Pasta	500	2	1000
Couscous	250	1	250
Rice	500	1	500
Peas (dried)	65	1	65
Carrots and Peas (Dried)	65	1	65
Beans (dried)	65	1	65
Tomato paste sachets-packet	200	1	200
Salt	bottle	1	
Pepper	shaker	1	
Desserts			

Apricots (dried)	200	1	200
Sultanas	375	1	375
Fruit (tinned)	430	2	860
Christmas Pudding	400	1	400
To Collect from the Field Support Officer (FSO)			
Bacon	250	2	500
Bread-swiss rye	700	2	1400
Cheese	500	2	1000
Salami	300	2	600
Frozen veges(mixed assortment)	500	2	1000
Frozen stirfry veges	500	2	1000
Frozen hashbrowns	750	2	1500
Frozen meat	250	10	2500
Total	**Weight**		**27.587kg**

Appendix III: Field Food Review 11 May 2004

Present: Katherine Fouhy (nutritionist) Laila Cooper (her supervisor), Jim Cowie, Peter Cleary.

We had a 1.5hour presentation by Katherine of her review of the nutrition of the current Field Food followed by a discussion. She will supply her power point to Keith after she has made some minor modifications, followed by a full report.

Katherine has reviewed:

- Nutritional Adequacy
- Food Quality
- Dietary modernity
- Practicability

She used the following methods:

- Literature review, she noted a lot of the existing research is from studies of expeditions to high altitude areas so there will be some difference to Antarctic conditions. Notable points were:
    - High calorific requirement (normal +15% usually)
    - Weight loss generally noted at altitude
    - She feels you would need to do a before and after study in Antarctica to get exact comparisons.
- A full analysis of the current contents of the box which she has compared to Recommended Daily Intake and the 1997 National Nutritional Study (NZ)
- Focus Group questioned which was very useful from her perspective about how it works in reality in a field situation, some points:
    - Group was only four person but all with field experience.
    - Did not include a vegetarian.
    - Did include a experienced FSO
- She did not include the large field groups operating on bulk and base food

Her initial comments are:

- The current Field Food is adequate but some areas may need some modification.
    - Field Food is high fat diet but needs to be energy dense and provided high levels of physical activity shouldn't be a cholesterol problem.
    - Poly saturated fat content is too high but mono saturated fat needs increase (this is primarily from the snack foods)
    - Carbohydrate content is too low
    - Vegetarians need wider range of vegetables to get all necessities.
    - Vegetarian diet needs to watch its calorie content
    - Stock control needs to be watched. Use First In, First Out principle.
    - But most use by dates not a great problem but watch dairy items
    - Affect of freezing of food seems generally ok but she suggests we return to processed cheese.

    - When variation is available make sure it is in each box (e.g. not all of one sort of bumper bar or dehy)
    - Make sure labelling is correct if repackaging items.
    - While frozen food has financial and personnel benefits (strongly liked) it needs to be watched for un-thawing in dry valleys & northern areas. Substitute dehy.
    - Lunches are an issue: high sugar content (but need calories) savoury items craved.
    - Make sure size of item is correct for 10 days for two people e.g. jam, but realises there are supply issues.
- Strongly suggests the AntNZ Recipe book be revived which could include recipes but also hints for inexperienced groups about:
    - Amount of calories required working in a cold environment.
    - Explain to vegetarians the calorific implications of their diet.
    - Some suggested meal lists from the Food box.
    - Hints on how to use a pressure cooker to cook various items.
    - General camp cooking hints, as many people seem to have limited practical knowledge.
- Good discussion about how much tailoring of boxes to different needs was possible:
    - Logistics problems noted.
    - Events can currently do but many aren't prepared to devote time.
    - When groups are mixed vegetarian/ non-vegetarian care needed.
    - You can't please all tastes (Laila Cooper noted hospitals aim for the main 90%)
    - Variation in type of vegetarian needs noting
    - Vegans are a problem